Journal of the Minnesota Academy of Science

Volume 2 | Number 3 Article 15

1881

Joseph Priestley

James A. Dodge

ism with powers to comprehend nature and anticipate something above and beyond it all, weaving muscles and nerves and bone and brain, each in its proper place and of proper proportions—this is something that the microscope does not reveal and calling it *the law of heredity* does not explain.

JOSEPH PRIESTLEY.

BY PROF. JAMES A. DODGE, UNIVERSITY OF MINNESOTA.

Our text-books of chemistry—even the briefest of them—inform us that oxygen gas was discovered in 1774, by Dr. Joseph Priestley. In 1874 the *centennial of oxygen*, if I may so term it, was celebrated. Commemorative meetings in honor of Priestley were held by scientific societies and by others, both in this country and in England. Addresses were delivered and articles published on the life and works of that remarkable man. It is, therefore, no new theme on which I have the honor of speaking before you. Nor can I profess to bring forward new facts relating to the subject. But one for whom the pursuit and the presentation of the phenomena of experimental chemistry have a strong and—to speak for myself—a wellnigh fascinating interest, and one whose attention is given to the scarcely less fascinating history of the development of chemical philosophy, such an one finds in the practical discoveries and theoretical views of Priestley a subject that seems always as good as new. My purpose, accordingly, is to review, in as concise and plain a manner as I may be able, with the help of some experimental illustrations, the principal points, in fact and in theory, that are connected with the subject.

In the first place, let us be reminded that Priestley was not by any means solely, or even principally, a *chemist* by training or occupation. He was a person of quite another profession at the outset, and indeed throughout life. Chemistry was merely his pastime. A dissenter, of a Calvinist family, born near Leeds, Yorkshire, in 1733, he was started early in the way of preparation for the ministerial calling. And that calling he followed. The popularity of a great preacher Priestley never reached. Nor was his pecuniary income ever very great. He was and remained poor in this world's goods, a fact to be remembered when we consider the number and the importance of his scientific discoveries. For it needs much money to supply the demands of a man whose hobby is a branch or branches of the experimental sciences. Friends of Priestley helped him a good deal, in mature life.

But though never especially popular as a preacher, Priestley was a scholar and a man of letters. His mind was one of great versatility. As an author his works comprise a very unusual range of subjects; and they were not less voluminous than various. Perhaps we may most quickly convince ourselves that he was not exclusively a chemist, and at the same time that he was not exclusively a theologian, by noting the titles of a few of his works. I will give a few of them: "A Harmony of the Evangelists;" "A Course of Lectures on Criticism;" "The rudiments of English Grammar, adapted to the use of Schools;" "A History of Electricity;" "A Disquisition relating to Matter and Spirit" (I have here this work from the library of the University); "A Treatise on Civil Government;" "A General History of the Christian Church;" six volumes of "Experiments and Observations on Different Kinds of Air" (I regret to say that I do not personally possess nor do I find in the library of the University, these interesting volumes containing the details of Priestley's experiments on the gases; I have had access to them elsewhere); to resume our list, "On the History and Recent State of Discoveries relating to Vision, Light and Colors;" "Considerations on the Doctrine of Phlogiston and the Composition of Water." The whole catalogue of Priestley's works comprises about one hundred volumes. The titles of some of those just mentioned are accounted for by the fact that he was for some years, in early life, tutor in an academy near Liverpool, where he taught Latin, Greek, French, History, Mathematics, Logic, *and a few other branches.* It can easily be imagined that Priestley never allowed himself much idle time; he was, evidently, a worker in the hive. And in him we have one example of an individual extending his attention over a broad range of subjects, and at the sane time gaining an acknowledged preeminence in one subject—perhaps it might be said of Priestley, in two.

With his extraordinary versatility, Priestley had early directed a part of his attention to certain branches of natural science. It was the science of electricity which first excited in him a lively interest. Benjamin Franklin being in England in 1763, Priestly, then at about the age of thirty, was fortunate enough to make his acquaintance, at Liverpool, and he was encouraged by Franklin in the study of Natural Philosophy. The result was Priestley's "History of Electricity," into which he brought some account of original investigations. The work was very well received. But I must now proceed to make more detailed reference to that part of his work for which he is, and will be, most noted and best remembered, namely his experiments and discoveries in the department of Chemistry

Priestly was a *phlogistian.* Let us make clear to ourselves what that was. It becomes necessary that I shall recapitulate the terms of that system or doctrine of *phlogiston* which pre-vailed a hundred years ago in the theory of chemistry.

(Exper.) I light a splinter of wood at the candle; it blazes up, and would presently burn almost entirely away. I can not light a piece of chalk, as I did the wood. Why is this? The reason, said the philosophers of the greater part of the last century, and Priestley as eminent among them, the reason is that the wood contains in itself a principle of inflammability and combustibility, which principle the chalk lacks. This principle of combustibility, an assumed delicate evanescent form of matter, of almost universal distribution, so abundant in the wood and almost lacking in the chalk, escaping in the whirling movement and flicker of flame when the wood is burned, had received from Stahl, of Germany, the principal originator of the theory, the name *phlogiston*, (a word from a root signifying *fire*). Let us look at other cases of its manifestation.

(Exper.) I light a piece of phosphorus with a hot wire on this little stand and quickly invert a glass jar over it closely. Phosphorus is very inflammable. Hence (in the language of the days to which we are going back) it must contain a large proportion of phlogiston, and this phlogiston is here escaping from it with great energy. And what else does the phosphorus contain? We notice the white fumes that have filled the jar with a dense cloud, but will presently settle down as a miniature snow-storm and cover the bottom. This white substance, said Priestly and his scientific associates, is the other constituent of the phosphorus. Of this white substance and phlogiston the phosphorus—a compound body—is made.

(Exper.) Let us now try another combustible substance. We will undertake to burn some metallic zinc. I have here a crucible of melted zinc heated very hot in this fire. I remove the cover from the crucible, and the zinc bursts into brilliant flame. This flame is a manifestation of the escape of phlogiston. We observe these white fumes that come from the burning metal, these flocks of "philosopher's wool" that float about in the air. They are the "calx of zinc," and the zinc itself—a compound body—is made up of this white calx and phlogiston. There is a perfect analogy to the composition of the phosphorus. Examples might be multiplied. Here is a ribbon of magnesium, the metal, twin-brother of zinc, but possessing even a larger share of phologiston. It lights at the (Exper.) flame of the candle and burns with great brilliancy, and here is the "calx" of magnesium, remaining constituent of said metal.

(Exper.) I sprinkle some iron filings in the flame of the spirit lamp. They too contain phlogiston, and show a calx.

Here is a quantity of litharge. It is the "yellow calx of lead," which appears when metallic lead is heated with access of air. Now if calx of lead be heated with charcoal, smelted, in short, lead is reproduced. The charcoal is rich in phlogiston which it gives up readily to other substances. It gives up phlogiston to the calx of lead, and thus the lead is made anew out of its components. Was it not a clear case of synthesis? Nothing clearer, said the phlogistians. But here arise two questions to be answered. The first is this: From a given weight of lead is obtained by calcination a certain weight of calx; how is it that the calx of lead *weighs more* than the lead of which it is said to be a constitment? Can the part be greater than the whole? This question about weight was partly neglected by the phlogistians, and partly, when it was no longer possible to neglect it, answered in circuitous and impractical ways, into which we will not now take time to enter. The other question is this: What is the part played by the *air* in these phenomena of combustion and calcination? Let us see.

(Exper.) Put a lighted candle into a bottle. Its light is soon extinguished. Stahl,—and Priestley as a phlogistian,—explained this phenomenon by assigning to the air the part of a great receptacle and absorbent of phlogiston. The less air, therefore, the less phlogiston could be absorbed; hence the air in the confined space of the bottle soon became saturated with phlogiston, "phlogisticated"; and then phlogiston must cease to be given off, and the candle must cease to burn.

Such was the doctrine of Chemistry with which Priestley, from early reading and from attendance at lectures, had familiarized himself. Such was the theoretical system that he fully adopted. And when Priestley had once adopted this system, he clung to it with all his Yorkshire tenacity, so that neither reason nor evidence could draw him from his persuasion. The existence and function of phlogiston became for him a leading article of faith; and of that faith he would seem to have constituted himself the chief defender. That phlogiston should be *produced* in corporal form, was not though a necessity. "Phlogiston *must* exist, therefore it does exist," might be put down as the ultimate dictum of those eighteenth century philosophers.

After this somewhat hasty recapitulation of the doctrine of phlogiston, reference to which was unavoidable, we will pass on to a review, also hasty, of the principal practical discoveries and experiments made by Priestly.

Happening to live near a brewery in Leeds, he became interested in the peculiarities of the gas produced by fermentation, which we now call carbonic acid gas, but which was then known as "fixed air." Priestley's ingenuity soon helped him to collect some of this gas for experiments and to produce it himself. (Exper.) I have here an arrangement for illustrating the production and collection of this gas from fermenting substances. In this case I have used a mixture of syrup and yeast. We readily show that this gas is a non-supporter of combustion. In order to observe its effect on the animal system when respired, Priestly introduced mice into vessels filled with it. He further made observations on its solubility in water, and in fact deserves credit for being the inventor of artificially carbonated water, or "soda water."

Priestley soon became expert in manipulating gases, making improvements in the pneumatic cistern for collecting gases over water. His form of this indispensable apparatus was essentially the same that I have here. We will (Exper.) suppose ourselves in the act of reproducing one of Priestley's experiments. I introduce into this jar in the pneumatic cistern a volume of air. Now I add thereto an equal quantity of that remarkable (colorless) gas that is produced when nitric acid is poured on pieces of copper. We see the effect. These red fumes are produced by the mixing of the two volumes, and now a contraction is apparent, due to an absorption of the fumes by the water; much less space is taken up than would be occupied by the two original volumes. Priestley thought that he had found in this process a method for measuring the state of the air, whether good or bad, by observing the amount of the contraction that we have noticed, pure air bringing about the greatest contraction. The method, however, after a time proved itself inadequate for useful purposes.

An invention wholly due to Priestly was the mercurial pneumatic cistern, the use of mercury in the same manner as water in the handling of gases. This was an invention of great value for chemistry. Important results immediately followed its introduction by Priestly. He was now able to collect and keep gases which could not be brought into contact with water without immediate absorption. Such a gas was that produced from the action of oil of vitriol on common salt. I have here some of this gas, collected (Exper.) and kept over mercury in this tube. The mercury "seals" it. I now take up the tube with some mercury and set it in this colored water. We see an immediate absorption of the gas by the water. This is the gas that is given off from muriatic acid; so the blue coloring of the water is turned red.

(Exper.) Here in this large bottle in another gas that is very soluble in water, ammonia gas. I open the tube running through the stopper and immerse it in this red-colored water. We see how energetically the water absorbs the ammonia gas and how it is forced into the bottle in a fountain by the pressure of the external air. Both these gases were obtained in vessels for experiment for the first time by Priestley.

Another kind of gas in whose nature and properties Priestley took great interest, though he was not its discoverer, was "inflammable air," the *hydrogen* of our day. Let me repeat, with a somewhat modified apparatus, an experiment of Priestley on this "inflammable air." In this bent tube (Exper.) I have some of this gas sealed by mercury at the bottom. In the closed, upper end of the tube is a quantity of dried black oxide of copper, "calx of copper" in the language of that period. I now heat the tube where the calx of copper lies, and presently there begins to be a diminution of the volume of the hydrogen gas. By taking time and care we could make the hydrogen disappear altogether. The calx of copper changes too; metallic copper shows itself in its place. In short, it appeared to Priestley that the "inflammable air" had united with the calx of copper to produce metallic copper. Ergo, what could inflammable air be but the all-important yet mysterious *phlogiston?* I will not trouble you with the detailed developments of this matter. The composition of water, key to the whole result, was not known till some years later. At last it was seen that the oxygen of the oxide of copper unites with the hydrogen in the tube, producing water, in minute quantity, and leaving copper as metal.

Another "inflammable air" discovered by Priestley, and for a time confounded with that just mentioned, was the gas that burns with a blue flame on the surface of our hard coal and charcoal fires, carbon monoxide. Here is a jar of (Exper.) this gas which I have prepared. I ignite it. You recognize the familiar blue flame, though here we have it in greater mass.

Passing over some other discoveries of Priestley, we come lastly to speak of his discovery of that gas which we now call *oxygen*. He first obtained it in 1774 by heating the red calx of mercury. Here, as he and others at once saw, was a great discovery. It was worth a life-time of study and labor. The relations of oxygen to animal life were immediately ascertained by Priestley. From the remarkable manner in which it supports and hastens combustion, as we (Exper.) see when I put this lighted candle into a bottle of the gas, Priestley called it "dephlogisticated air," that is, air which was without phlogiston and hence was ready to absorb great quantities of it from ignited bodies. The effect of this gas on various burning bodies were observed, and these effects have ever since been shown in familiar experiments. Though familiar, I will repeat two or three of them. (Exper.) Here we let sulphur burn in a jar of oxygen. Here we burn phosphorus in (Exper.) oxygen in this glass globe. (Exper.) Here a coiled steel spring burns up almost like a train of gunpowder.

Let me read some portion of Priestley's own words in reference to the gas with which we have just been dealing. He made the experiment of inhaling the gas.

"The feeling of it to my lungs was not sensibly different from that of common air; but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that in time this pure air may become a fashionable article in luxury? Hitherto only two mice and myself have had the privilege of breathing it. * * But perhaps we may infer from these experiments that, though pure dephlogisticated air might be very useful as a medicine, it might not be so proper for us in the usual healthy state of the body; for, as a candle burns out much faster in dephlogisticated than in common air, so we might, as may be said, live out too fast, and the animal powers be too soon exhausted in this pure kind of air. A moralist, at least, might say that the air which nature has provided for us is as good as we deserve."

Having these two remarkable gases, "inflammable air," and "dephlogisticated air," at hand, Priestley next studied the effects of burning them together. Here in this rubber bag I have a mixture of oxygen and hydrogen. (Exper.) I blow a few soap bubbles on this plate with the mixture and on igniting them we have a loud explosion. Priestly spent some time in investigating the proportions best suited for the explosive effects. He seems to have enjoyed producing a good round noise, and sometimes taking unawares friends who came to witness his experiments. (Exper.) Explode hydrogen and oxygen mixture in bladder by electricity.

We have thus passed in review, somewhat hastily, the principal discoveries of Priestley in the department of Chemistry. His work was, as has been seen, mostly confined to "pneumatic chemistry," the chemistry of the gases. I will not take time to relate the circumstances that led to his removal from Birmingham to this country. He settled in the little village of Northumberland, in the valley of the Susquehanna. Here, having declined the position of Professor of Chemistry in the College of Philadelphia, he still carried on his experiments, though under many disadvantages, and made some additional discoveries. He still, as ever, gave a large share of attention to the writing of treatises on theological questions. He died in 1804, still adhering to the doctrine of phlogiston, although that was already become a thing of the past, and all other phlogistians of note had struck their colors and acknowledged the authority of the new system, the anti-phlogistic system of Lavoisier and his followers. Almost the last work of Priestley from his Susquehanna home, was a disputation entitled "The Doctrine of Phlogiston Established, and that of the Composition of Water Refuted"

Such was the life of this remarkable man. It was a life filled with work, and that work marked with important results. For the discovery of oxygen must be reckoned, from its wide-reaching influence on so many branches of the practical arts, and from the revolution immediately occasioned by it in one great department of science, as one of the capital discoveries of modern times. If Priestley's mind had been less prepossessed by the notions of the ruling theory of the time of his youth and middle age, he would have added still greater honor to his name. How often had he the true interpretation of the great facts of the processes of combustion and calcination almost within his grasp! But his mind's eye was turned another way, and he let the truth slip from him. It slipped away from before the very eyes of Priestley, to be recognized and grasped by Lavoisier, an investigator not more endowed than Priestley with the talent for discovery, but a better trained student than Priestley, following more exact and refined methods, with a clearer and keener insight into the nature of things.

The phlogistic ideas were really a development of previously existing notions. The old belief in the material and elementary nature of fire, the conviction that like behavior of several substances must be due to the existence in those substances of a common ingredient, above all the neglect of sufficiently exact and careful investigation before adopting a conclusion—which had been eminently characteristic of what there was of natural science among the ancients—those conceptions and those defective methods, handed down through the middle ages, furnished the foundation of Stahl's peculiar and ingenious, but unstable system. Yet, when we put ourselves in the place of the phlogistians, with their outlook on the phenomena of matter and with their developed appliances, we shall be far from calling their theory an absurdity. And when we remember how it grouped together great classes of facts really related, and introduced system where there had been no system, we may admit that the adoption of the theory of phlogiston *was a step in advance.*